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Research Article

Utility of Accelerometers to Measure Physical Activity in Children Attending an Obesity Treatment Intervention

Wendy Robertson,[1] Sarah Stewart-Brown,[1] Elizabeth Wilcock,[2] Michelle Oldfield,[1] and Margaret Thorogood[1]

[1] *Health Sciences Research Institute, Warwick Medical School, University of Warwick, Coventry CV4 7AL, UK*
[2] *Biomolecular and Sport Sciences, Coventry University, Coventry CV1 5FB, UK*

Correspondence should be addressed to Wendy Robertson, w.robertson@warwick.ac.uk

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Objectives. To investigate the use of accelerometers to monitor change in physical activity in a childhood obesity treatment intervention. *Methods*. 28 children aged 7–13 taking part in "*Families for Health*" were asked to wear an accelerometer (Actigraph) for 7-days, and complete an accompanying activity diary, at baseline, 3-months and 9-months. Interviews with 12 parents asked about research measurements. *Results*. Over 90% of children provided 4 days of accelerometer data, and around half of children provided 7 days. Adequately completed diaries were collected from 60% of children. Children partake in a wide range of physical activity which uniaxial monitors may undermonitor (cycling, nonmotorised scootering) or overmonitor (trampolining). Two different cutoffs (4 METS or 3200 counts$\cdot$min^{-1}) for minutes spent in moderate and vigorous physical activity (MVPA) yielded very different results, although reached the same conclusion regarding a lack of change in MVPA after the intervention. Some children were unwilling to wear accelerometers at school and during sport because they felt they put them at risk of stigma and bullying. *Conclusion*. Accelerometers are acceptable to a majority of children, although their use at school is problematic for some, but they may underestimate children's physical activity.

1. Introduction

Accelerometers provide an objective measure of habitual activity which is not dependent on self-report, and are superior to pedometers because they measure the intensity of physical activity as well as frequency [1]. They are small portable devices, particularly suitable for measuring physical activity in free-living living conditions [1]. Research using accelerometers has escalated since the mid1990s [2].

Accelerometers operate on the principle that they measure change in velocity over time (acceleration) (m.s^{-2}), enabling intensity of physical activity to be quantified [3]. Accelerometers can be uniaxial, usually sensitive to movement in the vertical plane, or biaxial or triaxial, with movement also detected in the anteroposterior and/or lateral planes [4]. A known limitation with uniaxial (vertical) accelerometers is that they underestimate nonambulatory activities that do not involve vertical movement of the trunk (when waist mounted) such as cycling [4]. Triaxial accelerometers have a theoretical advantage over uniaxial monitors to capture non-ambulatory activities, although in reality they provide similar information due to dominance of detecting movement in the vertical plane [4].

Studies of the validity and reliability of accelerometers in children and protocols to standardise their use are available [4–6]. "Accelerometer counts" have been calibrated against energy expenditure [3], and researchers have published thresholds of activity counts equating to different intensities of physical activity [7–9]. There has been a focus on measuring moderate to vigorous physical activity (MVPA), as the level of physical activity deemed to improve health. Activities which constitute MVPA comprise brisk walking, jogging, and running [10]. However, there remains a lack of consensus in defining the intensity of physical activity with accelerometers, which is making comparison between studies difficult. For example, in UK school children there is a wide variation in the proportion reaching the Department of Health's [11] recommendation of 60 minutes of moderate intensity activity per day, from 2.5% in 11 year olds [12] to 92% in 13-14 year olds [13]. This large difference is thought to be due to different thresholds of accelerometer counts used to define moderate intensity activity.

The utility of an instrument includes factors relating to first, the monitor, such as technical limitations and data loss due to malfunction, and second, the participants, including adherence to data collection protocols and use of the monitor within their social context [14]. A study of the feasibility of using accelerometers in a population-based cross-sectional study of young adolescents shows data loss due to malfunction in 8.5% of participants, and 50% of the remaining students had the full 7 days of recording [15]. Using accelerometers in intervention studies to measure change in physical activity requires multiple testing and poses potentially greater practical challenges for researchers.

We have previously reported the evaluation of "*Families for Health*", a new group-based intervention for the treatment of childhood obesity for 7–11 year old children and their parents [16]. This paper gives further details on the practicalities of using accelerometers to measure change in habitual physical activity, providing new insight into their utility in children who are obese.

2. Methods

Data in this paper were gathered as part of the evaluation of "*Families for Health*", a treatment intervention for children who were obese or overweight and their parents from Coventry (England) [16]. Two "*Families for Health*" programmes were run. The first group of families commenced the programme in September, with followup in December and June; and the second group of families started the programme in January, with followup in April and October. These months are provided in order to understand any potential seasonal effect [12].

2.1. Data Collection with the Accelerometers. Children's physical activity levels were measured using a 7-day recording with a uniaxial (vertical) accelerometer with step-count function (GT1M Actigraph, Fort Walton, Florida) at three timepoints: baseline, end-of-the programme (3-months), and 9-months. As far as was practically possible, children wore the same monitor (serial number) at each time point, to remove "between unit" variation. Children were asked to wear the accelerometers during waking hours, removing them at bedtime and also during bathing and swimming, since they are not waterproof. The accelerometer was worn on an elastic belt around the waist, positioned on the right hip.

A recording over 7 consecutive days provides a reliable estimate of usual physical activity in children allowing for differences between weekday and weekend [17]. The data collection interval was 60 sec, chosen to allow the storage of a week of data. We acknowledge that this epoch length (rather than a shorter epoch length) may underestimate MVPA [4]. Children wore the monitor for a day before the data collection started in order to allow for habituation. A 3% increase in normal levels of activity has been found on the first day of recording in children [6].

2.2. Children's Diaries. Children, sometimes with help from parents, completed an activity diary alongside the accelerometer for 7 days (see the appendix). This was a pictorial "tick box" diary recording activities each hour, with a column for free text additional comments. There was also a space to record the time the accelerometer was put on and taken off. The purpose of the diary was to aid interpretation of the accelerometer output.

2.3. Analysis of Accelerometer Data. Not all the accelerometer records were complete. We included a child's record in the analysis if there were at least 4 complete days of data available, taken as the minimum needed to obtain a reliable measurement of habitual physical activity in children (reliability of 0.80) [17]. We defined a complete day as one where there was ≥7 hrs of data, after excluding periods in the day when the accelerometer appeared not to have been worn. Although 10 hours of worn time is often used, the reliability between 7 and 10 hours is not substantially different [18, 19]. In practice, wear time was usually greater than 7 hours.

Nonwear time was identified from the data by periods of ≥20 minutes of consecutive zero counts, making it unlikely that the monitor was worn [20, 21]. There is, however, no consensus for the minutes of continuous zeros for identifying non-wear time, ranging from 10 minutes [12] to 180 minutes [15] in studies in children. In some cases, the number of minutes has not been specified [19].

At each time point for each child, the mean accelerometer counts per minute and the mean daily step count were calculated. The mean daily time spent in moderate and vigorous physical activity (MVPA) was calculated using two different thresholds for MVPA, which are in use for the Actigraph:

(i) Freedson Equation (See [3, 7]). Activity counts were translated into METs using the Freedson equation with 4 METS used as the cutoff for MVPA. METs $= 2.757 + (0.0015 \times \text{counts}\cdot\text{min}^{-1}) - (0.08957 \times \text{age [yr]}) - (0.000038 \times \text{counts}\cdot\text{min}^{-1} \times \text{age [yr]})$.

(ii) Puyau (See [8]). An activity count of $\geq 3200\ \text{counts}\cdot\text{min}^{-1}$ was used as the cut-off for MVPA. Minutes spent in light physical activity was also calculated using Puyau's cut-off of 800 to 3199 accelerometer counts.

2.4. Statistical Analysis. To account for the hierarchical nature of the data induced by family clustering we fitted linear mixed models with random family effects to examine the differences between baseline, the end of the programme and 9-month followup, for counts per minute, minutes of

MVPA, minutes of light physical activity, and stepcounts. Analyses were conducted using SAS version 9.

2.5. Interviews with Parents. Semistructured interviews with 12 parents were carried out at their home by one of the authors (WR) just after the "*Families for Health*" programme. Purposive sampling was used to select a range of parents [22]. Interviews obtained parents' perceptions of the research measurements, which were required to optimise data collection and minimise respondent burden in subsequent research [23]. The stem question was "*What did you think of the research aspects of the programme, such as the measurements of height, weight and waist; questionnaires and interviews; and activity monitor?*"

Interviews were recorded, transcribed and analysed using the Framework Approach [24], using NVivo (Version 7). Only qualitative data with bearing on the use of accelerometers are presented.

2.6. Group Interviews with Children. Group interviews were also carried out with 16 children at the end of the programme. No child mentioned the accelerometers and so these did not provide any information and will not be discussed further.

2.7. Ethical Approval. This study was approved by Coventry Local Research Ethics Committee.

3. Results

3.1. Participants. 28 children (9 males, 19 females) aged 7–13 years who were overweight or obese [25] were recruited to the "*Families for Health*" intervention, completing baseline measurements. 22 children also completed followup measurements both at the end of the programme and at 9-month followup.

3.2. Wearing of Accelerometers. At each time point, around half of the children had accelerometer data for all 7 days (≥7 hrs worn time per day): 46% (13/28) at baseline, 41% (9/22) at the end of the programme, and 50% (11/22) at the 9-month followup. Over 90% of children had at least 4 days of data: baseline 93% (26/28), end-of-programme 96% (21/22), and 9-month follow-up 91% (20/22). Most records included at least one valid weekend day: baseline 86% (24/28), end-of-programme 86% (19/22), and 9-month follow-up 86% (19/22).

There were five records (from five different children) with less than 4-days data. In four cases this was because the child had not worn the accelerometer for sufficient days and in one case it was because the battery in the accelerometer failed.

3.3. Completion of Diaries. Adequately completed activity diaries (all days completed) were available from 68% (19/28) of children at baseline, 64% (14/22) at the end-of-programme, and 55% (12/22) at the 9-month followup. The other diaries were either not returned at all ($n = 6$) or completed poorly ($n = 21$) with days missing and/or lacking any detail in the final column about what children were doing.

3.4. Interpreting Accelerometer Data. Table 1 gives the changes in children's physical activity after participation in the childhood obesity treatment programme. No significant change from baseline was demonstrated in the average minutes spent per day in MVPA at the end of the "*Families for Health*" intervention or at the 9-month followup using either method of calculation. Accelerometer counts per minute did not change significantly either. The average daily step count was unchanged at the end of the programme, but increased significantly at the 9-month followup. This increase may indicate that children were becoming more active in daily living, although this activity was not of sufficient intensity to be picked up by change in the summary measures from accelerometer activity counts.

The children from the two pilot groups of "*Families for Health*" differed significantly in their response from baseline to the end of the programme, but not from baseline to the 9-month followup. For example, children from Group 1 reduced their mean daily MVPA using the Freedson equation from 71 minutes in September (baseline) to 64 minutes in December (end of programme) (−7 mins, 95% CI −22 to 6), whereas Group 2 showed a significant increase from 40 minutes in January (baseline) to 55 minutes in April (end of programme) (15 mins, 95% CI 1 to 30) ($P = .028$). Likewise, there were similar differences for the accelerometer counts, with Group 1 showing a reduction of −87 counts·min^{-1} (95% CI −180 to 7) from September to December, whereas Group 2 had an increase of 157counts·min^{-1} (95% CI −44 to 358) from January to April ($P = .015$). This may reflect a seasonal effect, with less activity in the winter months, rather than any differential impact of the programme [12].

The difference in the mean MVPA calculated by the two methods was striking: 60.2 versus 15.9 minutes at baseline (Table 1). Using the Freedson equation the cut-off point of 4 METS equated to a mean activity count of 1834 counts·min^{-1} at baseline, although this ranged from 1510 counts·min^{-1} for the youngest child (7 yrs) to 2515 counts·min^{-1} for the oldest child (13.7 yrs). Thus the activity count which defines MVPA is much lower using the Freedson equation [3, 7] in comparison with the 3200 counts·min^{-1} recommended by Puyau [8]. As a consequence, at baseline 10 of the 26 (38%) children met the daily recommendation of 60 minutes of moderate intensity physical activity [11] when the Freedson equation was used, whereas no children met this recommendation when a cut-off of 3200 counts·min^{-1} was used.

A number of children had very high peak activity counts (counts·min^{-1}) for some days. Greater than 20,000 counts·min^{-1} is considered the threshold for biological plausibility for the Actigraph [26], above which data would be invalid. Recordings showing these levels of accelerometer counts were explored using visual inspection of the data alongside the diary. Figure 1 shows an example in which this child reached 28,000 counts·min^{-1} between 3-4 pm. The diary showed that this child was participating

Table 1: Children's habitual physical activity recorded by an accelerometer (Actigraph), at baseline (0-months), end-of-programme (3-months), and nine-month followup in 22 children (intention to treat analysis).

	0-months Mean (SD) ($n = 18$)	3-months Mean (SD) ($n = 18$)	9-months Mean (SD) ($n = 18$)	0–3 month change ($n = 20$)		0–9 month change ($n = 19$)	
				Mean (95% CI)	P value	Mean (95% CI)	P value
MVPA-Freedson (mins/day)	60.2 (35.1)	65.4 (37.5)	62.8 (33.9)	6.4 (−6.7 to 19.4)	.320	3.3 (−10.1 to 16.6)	.612
MVPA-Puyau (mins/day)	15.9 (11.7)	18.6 (12.6)	17.8 (11.2)	2.9 (−2.3 to 8.1)	.258	2.3 (−3.4 to 8.0)	.405
Light-Puyau (mins/day)	142.3 (42.9)	144.2 (47.1)	152.4 (40.6)	7.0 (−15.5 to 29.4)	.523	10.8 (−8.2 to 29.8)	.247
Accelerometer Counts (counts$\cdot$min^{-1})	581 (197)	595 (229)	593 (151)	23 (−86 to 132)	.663	10.3 (−65 to 86)	.778
Step count (steps/day)	7455 (2648)	8153 (2358)	8953 (2054)	819 (−245 to 1884)	.124	1549 (653 to 2444)	.002

MVPA: Moderate & vigorous physical activity; *Mean data only on 18 children who had at least 4-days of data at each time-point, differences done on $n = 20$ for 0 to 3 month change, and $n = 19$ for 0–9 month change.

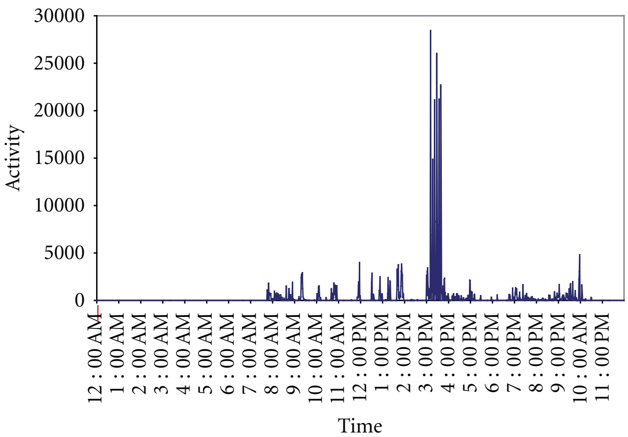

Figure 1: Record from the Accelerometer (activity counts) at the 9-month followup of a Child (16B) whose diary indicated that they were trampolining from 3-4 pm.

in trampolining at school (see the appendix). Four children specifically mentioned trampolining in their diary, suggesting that this is a common activity. At least two other children also had trampolines in their gardens, and in one diary "*playing in garden*" was recorded at the time when there were very high peak counts, indicating that they may have been on their trampoline. One other child with very high activity counts did not return her diary but her mother at interview commented about the trampoline in the garden: "*She's like 'Mum I'm going to go out and do my exercise 'cos it's light' and every night she's in the garden on the trampoline, she loves it.*"

The four records where trampolining was verified by the diary were analysed both with and without values above 20,000 counts$\cdot$min^{-1}, resulting in a mean reduction of 181 counts$\cdot$min^{-1} for the daily record and 50 counts$\cdot$min^{-1} when averaged over the weekly record. For the example in Figure 1, removal of six minutes of data between 3-4 pm where the activity counts were above 20,000 counts$\cdot$min^{-1} led to a reduction from 500 to 342 counts$\cdot$min^{-1} for that day, and from 413 to 388 counts$\cdot$min^{-1} for the summary record. These high counts are not "invalid" data per se, but it is of note that trampolining can lead to very high activity counts which can influence the summary record.

The physical activity the children were doing may also be undermonitored, due to the measurement abilities of the accelerometer used. A known limitation with uniaxial (vertical) accelerometers is that they underestimate activities that do not involve vertical movement of the trunk [4]. The diaries highlighted the wide range of activities in which children commonly partake which primarily involves horizontal movement (e.g., cycling, nonmotorised scooter riding, roller blading, ice skating) and may therefore be only partially monitored by the accelerometer (Table 2). We also asked children not to wear the monitor when swimming.

3.5. Participant Factors—Children Not Wearing the Accelerometers. Six parents volunteered information in the interviews about the accelerometers. Some children did not wear the accelerometers because they found them unacceptable when carrying out their usual activities of daily living including going to school, and playing sport.

3.5.1. Removal for Sporting Activity. Interview data confirmed that one boy was forbidden by the coach to wear the accelerometer when playing rugby, because being a contact sport it posed a risk of injury to others. Additionally, this child was a regular swimmer

(i) *The only problem was that with some of the activities that Child-4 does, he can't really wear it so you're not really getting the data for him when he's doing the activities. Because he can't wear it when he's swimming and he was going swimming most mornings, he can't wear it when he is playing*

Table 2: Children's Activity from their diary that is likely to be partially or wholly unmonitored by the Uniaxial Accelerometer.

	Baseline (n = 25 with diaries)	End-of-programme (n = 19 with diaries)	9-month follow-up (n = 22 with diaries)
Cycling			
1 day	2 children	1 child	4 children
2 days	2 children	—	—
3 days	2 children	1 child	—
4 days	—	—	1 child
5 days	—	—	1 child
6 days	—	—	—
7 days	1 child	1 child	—
Scooter Riding(non-motorised)			
1 day	—	2 children	1 child
2 days	3 children	1 child	—
3 days	1 child	—	—
Roller Blading/ Ice skating			
1 day	2 children	—	1 child
Swimming			
1 day	5 children	3 children	8 children
5 days	1 child	—	—
Episodes of partially or wholly "Unmonitored" Activity	46	18	24

rugby so you haven't really got a true reading of when he has done his activities. (Mother-4,Boy aged-10).

3.5.2. Unsightly Elastic Belt. Two parents complained that the elastic belt holding up the accelerometer was too obtrusive, and one parent suggested a clip as an alternative:

(i) *I think she did feel a bit embarrassed at first. I think when you tightened it a bit the thing [remaining elastic belt] came down, we tried to sort of shove it in the one together, she was alright after. (Mother-1, Girl aged-7).*

(ii) *I think because of the belt. You know like the pedometers maybe if it was something like that. [clip] When you've got the belt its more "ugh", you've got this big thing that goes right the way around you, and sometimes it flaps down, trying to tuck it in. (Mother-3, Girls aged 10 & 7).*

3.5.3. Stigma of Wearing Accelerometers at School. When one of us (WR) collected the monitors from their homes, several parents said that their child had not wanted to wear the monitor at school. One boy (aged-11) said that the accelerometer had caused him to be bullied by another pupil: "*you are wearing it because you are fat*". Parents raised similar issues in interviews. Girls in particular were unwilling to wear the accelerometer at school, due to stigma and bullying:

(i) *She didn't want to take it to school with her, she didn't want people knowing that she was wearing it. So she only really wore it when she was at home and you were only talking about a couple of hours between coming home and going to bed again and a lot of it, 'cos of the weather and different bits and pieces, she has been sitting. And again, you know he [friend on programme] did take it to school though, but maybe it's a girl thing. To be honest her Dad turned around and said she couldn't take it to school because it could get damaged or broken. But I suppose he said that but maybe he was thinking he didn't want people saying stuff about her. (Mother-5, Girl aged-9).*

(ii) *She didn't want to wear it initially. A fitness test in a fun way may be more productive than a monitor purely because you are relying on the children wearing the monitors, not getting teased at school, filling the diary out. (Mother-6, Girl aged-7).*

(iii) *It is just getting them to put it on. School could have a lot to do with it, she is conscious because of her weight and because her t-shirt is quite tight that it is going to be showing. (Mother-3, Girl aged-10).*

She also added that wearing the accelerometer was a particular problem during sport at school, due to embarrassment:

(i) *She is bothered about wearing it during the activities like netball and things because she is*

> *frightened her t-shirt is going to come up and because it is other classes, it's not just her own class. I did ask her today if she could wear it for netball tonight, I said it's only for practice, everybody knows you now, nearly everybody knows that you have got it on. So she said she might. (Mother-3, Girl aged-10).*

Accelerometers may be missing the physical activity of some of the children, either because of the technical limitations of the uniaxial accelerometer or due to children's unwillingness to wear them at school or during sport. However, around half of the children wore the monitor very conscientiously and provided 7 days of recording. As one parent reported:

> (i) *I think wearing the monitors to start with made Child-19 aware that it was serious, you know that there was a reason for doing it, he never once didn't wear it, he never once said he couldn't wear it or threw a tantrum, even when he went to his Dad's. And his Dad wasn't particularly supportive of the whole thing . . . even on the weekends when he was playing football with his Dad, as you know, he wore it. When we went to watch him [play in a football match] I said "have you got your monitor on?", and he was like "yeah" and showed it, so he took it seriously, he knew it was serious. (Mother-19, Boy aged-8).*

4. Discussion

This paper provides insight into the utility of accelerometers for measuring activity in children (in this case, children who were overweight or obese), including the acceptability of their use; an analysis of the physical activity which may be undermonitored; the results from different data reduction methods to derive minutes of MVPA.

Around 50% of the children provided 7 days of data and 90% had ≥ 4 days of data (the minimum required to be included in the analysis). This compliance is similar to a study in young adolescents in which 50% had 7 days and 86% had at least 4 days of valid accelerometer data, although a higher proportion of children who were overweight (66%) versus nonoverweight (46%) had 7 days of data [15]. Our experience with the Actigraph monitor was good with only one recording lost due to a fault with the monitor. Participant factors included forgetting to put the accelerometer on but some nonuse was related to children being unwilling to wear the monitor, particularly in school, because they were too conspicuous. In some cases the accelerometer had an unintended consequence of stigmatising the children and putting them at risk of bullying. The implication for loss of data in an intervention study is important. Because of missing data, only 18 of the 22 children who completed all the other research measurements had accelerometry data at each timepoint. This is reasonably good adherence to the protocol, and suggests that accelerometers are acceptable to most children but there are some children, in particular girls, who do not find it acceptable to wear accelerometers during their usual activities of daily living and, in some cases wearing the accelerometer was potentially harmful, because it encouraged bullying.

Accelerometers may have missed some of the physical activity that the children were engaged in for two reasons. First, children engage in a wide variety of physical activities which may not be captured by the uniaxial (vertical) accelerometer due to technical limitations [4]. Triaxial accelerometers, in principle, have a greater potential to capture the diverse activities in which children partake [18]. Second, children were not willing or able to wear them during sporting activities. For some sports children were requested to remove the monitors such as swimming (requested by the researchers) and rugby (requested by the coach), but some children were embarrassed and chose not to wear the monitor during sport at school. Thus the accelerometers are likely to have underestimated physical activity in the children in the current study, but the degree of underestimation is likely to vary between children.

UK guidelines recommend "*at least 60 minutes of at least moderate intensity physical activity each day*" for children [11]. The proportion of children estimated to meet this standard varies widely [12, 13]. Different conclusions may be due to different thresholds of accelerometer counts used to define MVPA [12]. In this study we had initially used the Freedson equation with a 4 METS threshold [3, 7] to derive minutes of MVPA [16]. However, we received feedback that the values for MVPA were too high, and reanalysis was conducted using a threshold of 3200 counts$\cdot$min^{-1} [8]. These two methods yielded very different results for both the minutes spent in MVPA, consistent with other studies [5, 27], and for the proportion of children reaching 60 minutes of physical activity per day. It is now accepted that the Freedson equation overestimates children's MVPA, and that the correct cut point is between 3000 to 3700 counts$\cdot$min^{-1} [5, 27]. Thus our data using Puyau's cut-off of 3200 counts$\cdot$min^{-1} for MVPA is likely to be the most accurate. Using this cutoff, none of the 26 children with 4 days of data at baseline achieved 60 minutes of daily moderate intensity physical activity, which is consistent with the low levels of physical activity in overweight and obese 11 year-old children in the ALSPAC cohort [12].

A common activity in children—trampolining—results in very high activity counts, and our data suggest that it may result in physical activity being "overmonitored". The physics of trampolining shows a peak acceleration of 4G [28], although the effect on the results from accelerometers in children is not widely discussed. Activity counts above 20,000 were recorded during trampolining, thought to be beyond biological plausibility for the Actigraph [26]. Very high activity counts with trampolining may negate the use of summary measures using raw activity counts (i.e., total daily activity counts or average counts$\cdot$min^{-1}) used in some studies with children [12], unless the trampolining data is removed prior to analysis. Trampolining could also affect the number of minutes spent in MVPA, because even gentle trampolining may take a child to an activity count above the threshold for MVPA. These findings suggest that

Table 3

Day: Thursday	Activity monitor put on: 7.30 am				Activity monitor taken off: 10.00 pm				
Time of day	Lying dowm	Sitting	Standing	Walking	Dancing	Swimming	Riding my bike	Running	What was your child doing? Please write down what your child was doing, for example watching TV, going to the park, playing football.
6 to 7 am									
7 to 8 am	✓		✓						Asleep, getting dressed
8 to 9 am		✓	✓						Eating breakfast, doing hair
9 to 10 am		✓							In car, in class
10 to 11 am		✓		✓					In class, break
11 to 12 noon		✓							In class
12 noon to 1 pm		✓							In class
1 to 2 pm		✓	✓						Eating dinner, class, firebell
2 to 3 pm		✓							Class, walking to PE block
3 to 4 pm			✓						Trampolining
4 to 5 pm		✓							In car, working
5 to 6 pm		✓							Working
6 to 7 pm		✓							Working
7 to 8 pm		✓	✓						Getting dressed, St Johns
8 to 9 pm		✓	✓						St Johns
9 to 10 pm		✓							Watching TV
10 to 11 pm									

trampolining should be given a specific column on our daily diary. Trampolining is physical activity, but further assessment of its impact on summary measures is warranted, and further consideration should be given to how best to account for trampolining in analysis. Caution must be exercised in the quality control and reduction of accelerometer data in children where trampolining is a relatively common activity.

This study has contributed an insight into the perceptions of parents on the use of the accelerometer with children who are obese. The findings are strengthened by using a diary alongside the accelerometer records to aid interpretation. Limitations of the study include that standardisation across the followup timepoints, although attempted, was not always possible due to logistics [29]. Followup was made at 3 and 9 months from baseline, whereas a 12-month follow-up is desirable in intervention studies so that results are not distorted by known seasonal changes [12]. A further limitation is that, whilst children were offered the opportunity of commenting on any aspect of the study, they were not explicitly asked about their perception of wearing the monitors in their daily living.

Researchers should be aware that not all physical activity is likely to be monitored by uniaxial accelerometers. Further validation studies in children performing activities such as scootering (non-motorised), cycling, roller blading, and ice skating should compare the output from triaxial and uniaxial monitors. Researchers must also be aware of the potential for harm, such as stigma and bullying of the obese child when they are singled out to wear the monitor to evaluate an obesity treatment intervention, and make efforts to minimise these risks [30]. Acceptability to children, in particular girls, could be improved by using attachments other than the elastic belt, such as a clip. Improved communication with the child's school about the childhood obesity treatment intervention may also be of value to increase the acceptability of wearing the accelerometer at school. Alternatively, monitoring could be done in the school holidays throughout the intervention. Further studies with children are indicated to gain their perception of wearing the accelerometers, similar to the study in adults by Perry [14].

In conclusion, although accelerometers are recognised as an objective measure of physical activity, the analysis of the diary records and interview data suggest some issues with their use in children.

Appendix

Activity Diary to Use alongside the Accelerometer (Completed Here for Child 16 B when Trampolining, 3-4 pm)

See Table 3.

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References

[1] M. J. Mathie, A. C. F. Coster, N. H. Lovell, and B. G. Celler, “Accelerometry: providing an integrated, practical method for long-term, ambulatory monitoring of human movement,” *Physiological Measurement*, vol. 25, no. 2, pp. R1–R20, 2004.

[2] R. P. Troiano, “A timely meeting: objective measurement of physical activity,” *Medicine and Science in Sports and Exercise*, vol. 37, no. 11, pp. S487–S489, 2005.

[3] P. Freedson, D. Pober, and K. F. Janz, “Calibration of accelerometer output for children,” *Medicine and Science in Sports and Exercise*, vol. 37, supplement 11, pp. S523–S530, 2005.

[4] K. Corder, S. Brage, and U. Ekelund, “Accelerometers and pedometers: methodology and clinical application,” *Current Opinion in Clinical Nutrition and Metabolic Care*, vol. 10, no. 5, pp. 597–603, 2007.

[5] J. J. Reilly, V. Penpraze, J. Hislop, G. Davies, S. Grant, and J. Y. Paton, “Objective measurement of physical activity and sedentary behaviour: review with new data,” *Archives of Disease in Childhood*, vol. 93, no. 7, pp. 614–619, 2008.

[6] C. Mattocks, A. Ness, S. Leary et al., “Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision,” *Journal of Physical Activity and Health*, vol. 5, no. 1, pp. S98–S111, 2008.

[7] S. G. Trost, R. Way, and A. D. Okely, “Predictive validity of three ActiGraph energy expenditure equations for children,” *Medicine and Science in Sports and Exercise*, vol. 38, no. 2, pp. 380–387, 2006.

[8] M. R. Puyau, A. L. Adolph, F. A. Vohra, and N. F. Butte, “Validation and calibration of physical activity monitors in children,” *Obesity Research*, vol. 10, no. 3, pp. 150–157, 2002.

[9] C. Mattocks, S. Leary, A. Ness et al., “Calibration of an accelerometer during free-living activities in children,” *International Journal of Pediatric Obesity*, vol. 2, no. 4, pp. 218–226, 2007.

[10] N. Armstrong and S. Bray, “Physical activity patterns defined by continuous heart rate monitoring,” *Archives of Disease in Childhood*, vol. 66, no. 2, pp. 245–247, 1991.

[11] Department of Health, “At least five a week : evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer,” Tech. Rep., Department of Health, London, UK, 2004, http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4080994.

[12] C. J. Riddoch, C. Mattocks, K. Deere et al., “Objective measurement of levels and patterns of physical activity,” *Archives of Disease in Childhood*, vol. 92, no. 11, pp. 963–969, 2007.

[13] L. M. Alexander, J. Inchley, J. Todd, D. Currie, A. R. Cooper, and C. Currie, “The broader impact of walking to school among adolescents: seven day accelerometry based study,” *British Medical Journal*, vol. 331, no. 7524, pp. 1061–1062, 2005.

[14] M. A. Perry, P. A. Hendrick, L. Hale et al., “Utility of the RT3 triaxial accelerometer in free living: an investigation of adherence and data loss,” *Applied Ergonomics*, vol. 41, pp. 469–476, 2010.

[15] P. A. Van Coevering, L. Harnack, K. Schmitz, J. E. Fulton, D. A. Galuska, and S. Gao, “Feasibility of using accelerometers to measure physical activity in young adolescents,” *Medicine and Science in Sports and Exercise*, vol. 37, no. 5, pp. 867–871, 2005.

[16] W. Robertson, T. Friede, J. Blissett, M. C. J. Rudolf, M. Wallis, and S. Stewart-Brown, “Pilot of “families for health”: community-based family intervention for obesity,” *Archives of Disease in Childhood*, vol. 93, no. 11, pp. 921–928, 2008.

[17] S. G. Trost, K. L. McIver, and R. R. Pate, “Conducting accelerometer-based activity assessments in field-based research,” *Medicine and Science in Sports and Exercise*, vol. 37, supplement 11, pp. S531–S543, 2005.

[18] K. Corder, U. Ekelund, R. M. Steele, N. J. Wareham, and S. Brage, “Assessment of physical activity in youth,” *Journal of Applied Physiology*, vol. 105, no. 3, pp. 977–987, 2008.

[19] V. Penpraze, J. J. Reilly, C. M. MacLean et al., “Monitoring of physical activity in young children: how much is enough?” *Pediatric Exercise Science*, vol. 18, no. 4, pp. 483–491, 2006.

[20] M. S. Treuth, N. E. Sherwood, N. F. Butte et al., “Validity and reliability of activity measures in African-American girls for GEMS,” *Medicine and Science in Sports and Exercise*, vol. 35, no. 3, pp. 532–539, 2003.

[21] J. Stevens, D. M. Murray, C. D. Baggett et al., “Objectively assessed associations between physical activity and body composition in middle-school girls,” *American Journal of Epidemiology*, vol. 166, no. 11, pp. 1298–1305, 2007.

[22] C. Teddlie and F. Yu, “Mixed methods sampling: a typology with examples,” *Journal of Mixed Methods Research*, vol. 1, no. 1, pp. 77–100, 2007.

[23] N. M. Bradburn, “Respondent Burden,” University of Chicago, 1978, http://www.amstat.org/sections/SRMS/proceedings/papers/1978_007.pdf.

[24] J. Ritchie and L. Spencer, “Qualitative data analysis for applied policy research,” in *Analysing Qualitative Data*, A. Bryman and R. Burgess, Eds., pp. 173–194, Routledge, London, UK, 1993.

[25] T. J. Cole, J. V. Freeman, and M. A. Preece, “Body mass index reference curves for the UK, 1990,” *Archives of Disease in Childhood*, vol. 73, no. 1, pp. 25–29, 1995.

[26] L. C. Mâsse, B. F. Fuemmeler, C. B. Anderson et al., “Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables,” *Medicine and Science in Sports and Exercise*, vol. 37, no. 11, pp. S544–S554, 2005.

[27] C. B. Guinhouya, H. Hubert, S. Soubrier, C. Vilhelm, M. Lemdani, and A. Durocher, “Moderate-to-vigorous physical activity among children: discrepancies in accelerometry-based cut-off points,” *Obesity*, vol. 14, no. 5, pp. 774–777, 2006.

[28] T. Irvine, “Human vibration on a trampoline,” Vibrationdata, Newsletter, 2-6, April 2005, http://www.vibrationdata.com/Newsletters/April2005_NL.pdf.

[29] O. Gavarry, M. Giacomoni, T. Bernard, M. Seymat, and G. Falgairette, “Habitual physical activity in children and adolescents during school and free days,” *Medicine and Science in Sports and Exercise*, vol. 35, no. 3, pp. 525–531, 2003.

[30] Economic and Social Research Council, “Framework for Research Ethics (FRE),” 2010, http://www.esrcsocietytoday.ac.uk/ESRCInfoCentre/opportunities/research_ethics_framework/.